DTU Library

Large Marine Ecosystems and coastal water archetypes implemented in LCIA methods for marine eutrophication and metals ecotoxicity

Cosme, Nuno Miguel Dias; Dong, Yan; Hauschild, Michael Zwicky

Publication date:
2014

Citation (APA):
Cosme, N. M. D., Dong, Y., & Hauschild, M. Z. (2014). *Large Marine Ecosystems and coastal water archetypes implemented in LCIA methods for marine eutrophication and metals ecotoxicity*. Poster session presented at SETAC Europe 24th Annual Meeting, Basel, Switzerland.

DTU
Technical University of Denmark

Quantitative Sustainability Assessment
Department of Management Engineering

Produktionstorvet 426
2800 Kgs. Lyngby, DENMARK
www.qsa.man.dtu.dk

Large Marine Ecosystems and coastal water archetypes implemented in LCIA methods for marine eutrophication and metals ecotoxicity

Nuno Cosme (nmdc@dtu.dk), **Yan Dong, Michael Z. Hauschild**

TU260

Summary

- Modelling framework for **marine eutrophication** (**MEu**) and **marine metals ecotoxicity** (**MEc**).
- Characterisation Factors (**CFs**) integrate **Fate**, **Exposure** or **Bioavailability**, and **Effect** Factors.
- 64 **Large Marine Ecosystems** (**LME**) – spatial units of coastal areas for spatial differentiation.
- **Residence Time** (**RT**) for nitrogen and metals is required for the parameterisation of fate models.
- RT expresses the flushing of the system and the **losses** of nitrogen/metals by advection.
- RT data was found in **literature** or obtained from **4 archetypes** defined by hydrodynamics.

Conclusions !

- The **LME classification system** was chosen for its data availability, modelling feasibility, and adequacy of size and number of spatial units.
- **Archetypical RT** data was a useful solution for the parameterisation needs of the fate models.
- The **spatial differentiation** of the resulting CFs was found essential to increase the discriminatory power of the models.

Background

Marine Eutrophication (MEu)

- Ecosystem response to excessive input of nitrogen (N) with increase of primary production in the photic zone of coastal waters [1].
- Heterotrophic bacteria respire the accumulated organic matter consuming dissolved oxygen.
- Excessive depletion of oxygen may lead to hypoxic stress of benthic organisms and loss of biodiversity.

Marine metals Ecotoxicity (MEc)

- Response of ecosystems to excessive level of metals in the integrated environment [2].
- Organisms become exposed to excessive metals concentration in marine water.
- Exposure may lead to uptake of metals and toxicity effect by e.g. decreasing or blocking the uptake of essential elements by binding with the transporters.

Life Cycle Impact Assessment (LCIA)

- Characterisation modelling of environmental mechanisms.
- Characterisation Factors (**CFs**) are used in LCIA to convert emissions into impacts.

Methodology

① LCIA indicators

- The **MEu** indicator expresses the eutrophying impact of nitrogen (N).
- **MEc** the toxic impact of metals emissions to the marine environment.

Characterisation Factor for Marine Eutrophication:

- Fate of N (FF), habitat Exposure Factor (XF), and Factor for the Effects on biota (EF).

$$\boldsymbol{CF}_{[PAF\cdot m^3\cdot d\cdot kgN^{-1}]} = \boldsymbol{FF}_{[d]} * \boldsymbol{XF}_{[kgO_2\cdot KgN^{-1}]} * \boldsymbol{EF}_{[PAF\cdot m^3\cdot kgO_2{}^{-1}]}$$

Characterisation Factor for Marine metals Ecotoxicity:

- Fate of metals (FF), Bioavailability Factor of metals (BF), and Effect Factor on biota (EF)

$$\boldsymbol{CF}_{[PAF\cdot m^3\cdot d\cdot kgMetal^{-1}]} = \boldsymbol{FF}_{[d]} * \boldsymbol{BF}_{[-]} * \boldsymbol{EF}_{[PAF\cdot m^3\cdot kgMetal^{-1}]}$$

② Models parameterisation

- Residence Time (RT) is applied in the Fate terms of both models:

Fate modelling in Marine Eutrophication:

$$FF_{LME} = \frac{f_{exp}}{\lambda_{LME}}$$

f_{exp} [-] is the fraction of the emitted N that reaches coastal marine waters (exported)
λ_{LME} [d^{-1}] is the N-loss rate coefficient in each LME

- The N-losses ($\boldsymbol{\lambda}$) can be caused by denitrification, advection and sedimentation:

$$\lambda_j = \lambda_{denitrification} + \boldsymbol{\lambda_{advection}} + \lambda_{sedimentation}$$

- The N-loss by advection is estimated with the residence time ($\boldsymbol{\tau}$) on each LME:

$$\boldsymbol{\lambda_{advection}} = \frac{\mathbf{1}}{\boldsymbol{\tau_{LME}}}$$

Fate modelling in Marine metals Ecotoxicity:

- Multi-media fate model embedded in USEtox®.
- Models losses by advection with **RT**, plus metals removal by sedimentation and diffusion to sediment.

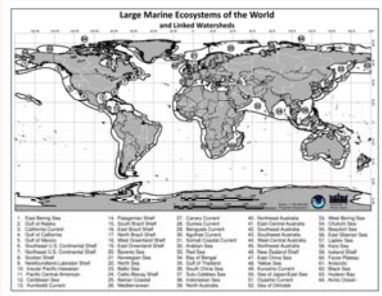
③ Residence time and archetypes

- The 4 archetypes are defined by the exposure to currents and regional marine circulation, depth and profile of the continental shelf, and water stratification:
  - **Archetype 1** (*high dynamics and exposure*): **RT=3 months**
  - **Archetype 2** (*medium dynamics and exposure*): **RT=2 years**
  - **Archetype 3** (*low dynamics*): **RT=25 years**
  - **Archetype 4** (*very low dynamics, embayed, often stratified*): **RT=90 years**
- ***Assumption***: System dynamics determines the RT of both N and metals in the water column.

Results

Spatial units

- Biogeographical classification system.
- **Large Marine Ecosystems (LME).**
- **64 spatial units** of coastal marine waters.
- Neritic zone from river basins and estuaries to the seaward boundaries of continental shelves.
- Distinct bathymetry, hydrography, productivity and trophically dependent populations [3].
- Mixing processes , light and nutrients.



The Large Marine Ecosystems (LME) spatial units

! **Number and size of spatial units.**

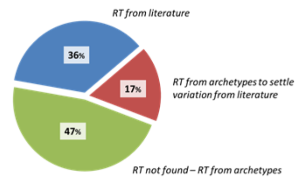
! **Integrated approach: productivity and oceanography, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance [4].**

! **Data availability for productivity, residence species, currents and circulation, and ease of adaptation to a climate zonation.**

! **The LME classification system was adopted for both MEu and MEc, out of a comparison of 13 alternative zonation systems.**

Distribution of data sources for Residence Time (RT)

- RT from literature (36% of LMEs).
- 4 archetypes used for the remaining to:
- Provide RT data (47%),
- Settle differences in sources (17%).



Residence Time (RT) dataset and sources: Literature and archetypes

LME #. name	RT [yr]	Source Archetype	 Litterature
1. East Bering Sea	2.00	2	
2. Gulf of Alaska	0.25	1	
3. California Current	0.25	1	
4. Gulf of California	1.50		Lopez & Garcia (2003) J Geophys Res 108(C2):3048
5. Gulf of Mexico	90.00	4	** Turner & Rabalais (2009) 2009_Hypoxia_Forecast.pdf, www.gulfhypoxia.net* *USGS (2012) toxics.usgs.gov/hypoxia/mississippi/oct_jun/index.html* *Rivas et al. (2005) J Phys Oceanogr 35:1763–1781*
6. Southeast U.S. Continental Shelf	0.25	1	** Alegria et al. (2000) Mar Pollut Bull 40(12):1178-1185*
7. Northeast U.S. Continental Shelf	0.25	1	
8. Scotian Shelf	0.07	1	** Smith et al. (2003) J Geophys Res 108:8013*
9. Newfoundland-Labrador Shelf	0.25	1	
10. Insular Pacific-Hawaiian	0.25	1	
11. Pacific Central-American	0.25	1	
12. Caribbean Sea	0.21		Molinari et al. (1980) Proc 32 Ann Gulf & Caribbean Fisher Inst 106-113.
13. Humboldt Current	0.03		Hall et al. (1996) LOICZ/R&S/96-9
14. Patagonian Shelf	0.25	1	
15. South Brazil Shelf	0.25	1	
16. East Brazil Shelf	0.25	1	** Attisano et al. (2008) Braz J Oceanogr 56(3):189-200*
17. North Brazil Shelf	0.25	1	** Limeburner et al. (1995) J Geophys Res 100(C2):2401–2415*
18. West Greenland Shelf	0.25	1	
19. East Greenland Shelf	0.25	1	
20. Barents Sea	2.00	2	
21. Norwegian Sea	2.00	2	
22. North Sea	2.00		Blaas et al. (2001) Clim Res 18:47–54
23. Baltic Sea	25.00		Jansson B-O (1980) Ambio 9:128; Matthäus & Schinke (1999) Hydrobiologia 393:1–10
24. Celtic-Biscay Shelf	2.00	2	
25. Iberian Coastal	0.25	1	
26. Mediterranean	90.00	4	** Pinet (2008) Invitation to Oceanography. Jones & Barlett.*
27. Canary Current	0.25	1	
28. Guinea Current	3.10		Hall et al. (1996)
29. Benguela Current	0.25	1	
30. Agulhas Current	2.00	2	
31. Somali Coastal Current	0.25	1	** Naqvi (2012) www.unep.org/stap/Portals/61/stap/Naqvi.pdf*
32. Arabian Sea	6.50		Sarma (2002) Global Biogeochem Cycles 16(4):1082
33. Red Sea	40.00		Smeed (2010) krse.kaust.edu.sa; Grasshoff (1969) "Meteor" während Ind Ozean Exped 1964/65; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon
34. Bay of Bengal	12.00		Sarma (2002) Global Biogeochem Cycles 16(4):1082
35. Gulf of Thailand	0.04		Dulaiova et al. (2006) Limnol Oceanogr 51(5):2232–2247
36. South China Sea	25.00	3	
37. Sulu-Celebes Sea	25.00	3	** Tessler (2012) PhD Thesis. Columbia Univ;* *Tessler et al. (2011) Geophys Res Lett 38:L18606*
38. Indonesian Sea	0.75		Ffield & Gordon (1992) J Phys Oceanogr 22:184–195
39. North Australia	0.25	1	
40. Northeast Australia	0.25	1	** Choukroun et al. (2010) J Geophys Res 115:C06013*
41. East-Central Australia	0.25	1	
42. Southeast Australia	0.25	1	
43. Southwest Australia	0.25	1	
44. West-Central Australia	0.25	1	
45. Northwest Australia	0.25	1	
46. New Zealand Shelf	0.25	1	
47. East China Sea	1.90		Tsunogai et al. (1997) J Oceanogr 53:9–17; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon; Hall et al. (1996) LOICZ/R&S/96-9
48. Yellow Sea	2.00		Tsunogai et al. (1997) J Oceanogr 53:9–17; Tomczak & Godfrey (2003) Regional Oceanography. Pergamon
49. Kuroshio Current	2.30		Matsuno et al. (2009) Ocean Sci Discuss 6:741–764
50. Sea of Japan/East Sea	25.00	3	
51. Oyashio Current	0.25	1	
52. Sea of Okhotsk	2.00	2	Yamamoto et al. (2001) J Geophys Res 106(C12):31075–84
53. West Bering Sea	0.25	1	
54. Chukchi Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
55. Beaufort Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
56. East Siberian Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
57. Laptev Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
58. Kara Sea	3.50		Schlosser et al. (1994) Deep Sea Res Part I 41(7): 1053–1068
59. Iceland Shelf	0.25	1	
60. Faroe Plateau	0.25		Gaard (2000) ICES J Mar Sci 57: 1605–1671
61. Antarctic	6.00		Jacobs et al. (1985) In Jacobs, Antarctic Research Series 43:59–85
62. Black Sea	90.00	4	** Murray et al. (2007) In Yanko-Hombach et al., The Black Sea Flood Question. Springer*
63. Hudson Bay	6.60		Ingram & Prinsenberg (1998) In Robinson & Brink, The Sea, vol 11. John Wiley & Sons
64. Arctic Ocean	11.00		Jahn et al. (2010) J Geophys Res 115:C07015

** used to average or settle divergent data*

This research was partly financial supported by the EU Commission under the Seventh Framework Programme Environment through:

- Project LC-IMPACT: Development and application of environmental Life Cycle Impact assessment Methods for imProved sustAinability Characterisation of Technologies (Grant agreement No.: 243827 – LC-IMPACT) - ENV.2009.3.3.2.1: Improved Life Cycle Impact Assessment methods (LCIA) for better sustainability assessment of technologies.
- Project PROSUITE: PROspective SUstaInability Assessment of TEchnologies (Grant agreement No.: 227078 – PROSUITE) - ENV. 2008.3.3.2.1: Improved Life Cycle Impact Assessment methods (LCIA) for better sustainability assessment of technologies.

Presented at: Basel 2014 SETAC Europe

References:

[1] Nixon SW (1995) Ophelia 41:199-219
[2] Truhaut R (1977) Ecotoxicol Environ Saf 1(2):151–173
[3] Sherman K & Duda AM (1999) Fisheries 24(12):15-26
[4] Spalding MD, Fox HE, Allen GR, et al. (2007) BioScience 57(7):573-583